Characterization of Caribbean Meso-Scale Eddies

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LONG-TERM GOALS

Our long-term goal is to improve predictivity of physical, biogeochemical and optical properties of Eastern Caribbean waters under the influence of mesoscale eddies and their interaction with regional features (i.e. massive riverine discharge). An expected outcome from this research is the capacity to infer susbsurface properties and processes as well as their temporal and spatial evolution utilizing remotely acquired surface observations.

This program will contribute to the development of infrastructure for marine research and education at the University of Puerto Rico. A particular expectation is the recruitment and training of graduate students who will focus their graduate research in current scientific issues attuned with the above expressed goals.

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14. ABSTRACT

Our long-term goal is to improve predictivity of physical, biogeochemical and optical properties of Eastern Caribbean waters under the influence of mesoscale eddies and their interaction with regional features (i.e. massive riverine discharge). An expected outcome from this research is the capacity to infer susbsurface properties and processes as well as their temporal and spatial evolution utilizing remotely acquired surface observations.

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SPECIFIC OBJECTIVES

- To determine the distribution of physical, chemical, biological and optical variables across frontal and eddy boundaries in the Eastern Caribbean Sea
- To develop sub regional derivation of empirical relationships between horizontal and vertical physical/chemical gradients and remotely sensed ocean properties
- Verification of inherent optical properties predicted by NRL's Automated Software System
- Verification of the eddy structure and trajectory predictions by the $1/16^o$ operational global NRL Layered Ocean Model
- Correlations phytoplankton pigment composition and size class distribution to inherent optical properties

APPROACH

We are implementing a series of research cruises to carry out observations of the optical and physical structure and upper water column biogeochemistry of eddies. Eddy distribution and displacement will be followed using the output from $1/16^o$ operational global Naval Research Laboratory (NRL) Layered Ocean Model (NLOM), near real time altimetry data, SeaWiFS and MODIS imagery (F.Gilbes). During research cruises we will obtain continuous flow surface records of T, S and Chl-a (J. Corredor), vertical sections of these variables plus apparent optical properties using the Nν-shuttle undulating towed body (J. Lopez). Discrete vertical profiles (J. Morell, J. Corredor) of physical (T, S), chemical (DO, nutrients, CDOM), biological and inherent (a, b, c) and apparent (R, R_{RS}, T, K_z) optical properties (F. Gilbes) will be obtained. Selected samples will be subjected to 3-D spectrofluorometry and scanning spectrophotometry for CDOM characterization (J. Corredor, J. Morell). Current structure across fronts and eddies will be characterized by means of ship-lowered ADCP current profiler (J. Capella). These studies will also include assessment of rates of biomass accumulation, primary production and photosynthetic efficiency (J. Lopez).

WORK COMPLETED

Cruise CaVortEx I aboard R/V CHAPMAN, August 12 – 19 2003 was undertaken in order to characterize a cyclonic eddy detected by satellite altimetry and ocean color traversing the east-central Caribbean Sea. The eddy, approximately 230 km in diameter was, observed as a sea surface height (SSH) anomaly by satellite altimetry in July 2003. Subsequently, SeaWiFS ocean color imagery revealed that the eddy core, at the time centered ca. latitude 14.8 ^{o} N and longitude 067.8 ^{o} W, was surrounded by a high-chlorophyll (HC) surface water mass. Imagery showed this as a large filament continuous with the Orinoco/Amazon River plume, creating a spiral pattern of alternating bands of HC and LC (low-chlorophyll) surface water with HC waters occupying the entire periphery of the eddy enclosing a core of LC waters. The cruise track, a diametric north-south section across the eddy with observations extending to 1000 m depth, allowed characterization of the physical, chemical, optical and biogeochemical structure of the eddy.

RESULTS

Observations during the initial filed campaign CaVortEx I confirmed the applicability of ocean color imagery to determine the precise location of eddies, particularly when these interact with Chlorophyll/CDOM-rich river plume waters (Figure 1). Eddy core position estimates based on ocean altimetry were displaced to the east (the oncoming direction) of the actual position probably due to data smoothing procedures.

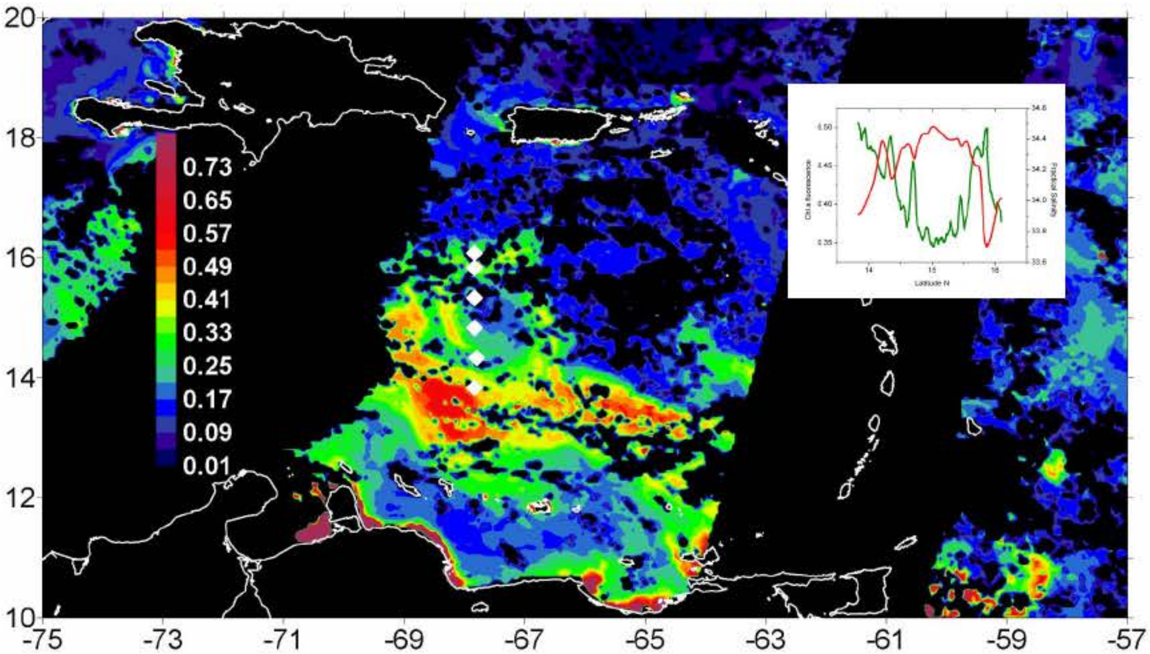

Figure 1: Contour plot of MODIS Chl-a data product for 14 August 2003 [Oceanographic stations and dates occupied aboard R/V CHAPMAN during the Caribbean Vorticity Experiment (CaVortEx I) are superimposed as white diamonds. The eddy core in the image is located approximately 14^0 50' N 067^0 50' W. Higher-chlorophyll, near-surface river plume water (reds and greens) surrounds lower-chlorophyll near-surface waters of the eddy core (blue). A filament of plume water spirals within the eddy core. Real-time shipboard salinity and chlorophyll-a measurements across the track (inset) closely reflect the pattern observed in the satellite imagery, yet surface Chlorophyll-a concentrations, calculated with the MODIS algorithm, exceed those observed in-situ by a factor of ca. 2.5.]

The hydrography evidenced moderate doming of the isopycnals down to ca. 800m with no evident near surface cross-isopycnal mixing. The salinity section evidences interaction of the eddy with the Orinoco/Amazon river plume. Contrary to purely oligotrophic oceanic eddies, the eddy -plume interaction resulted in the eddy core area exhibiting relatively higher upper water transparency than in non-eddy areas thus the presence of a deeper Chl a maximum.

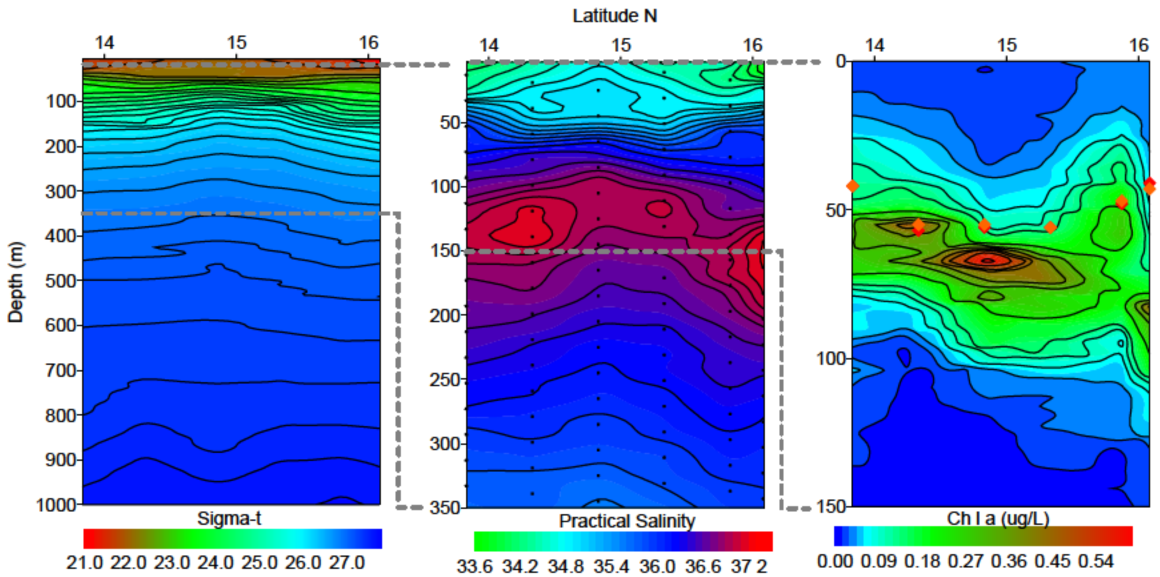

Figure 2: North South oceanographic section of the cyclonic eddy.
[Left: Baroclinic structure of the eddy is apparent in the seawater density (sigma-t) section as a dome extending throughout the top of the water column to ca. 700 m, below which, isopycnals exhibit a negative dip. Center: High-salinity oceanic waters interact with the low-salinity plume water in the upper portion of the dome.
Right: As the subsurface influence of the northern edge of the eddy dome extends beyond the surrounding surface river filament, high chlorophylls in the buoyant plume create a halo around the doming, deep chlorophyll maximum (DCM) of the eddy. Low light availability in waters directly below the plume limits the abundance of phytoplankton and results in attenuation of the oceanic DCM.]

IMPACT/APPLICATIONS

Cyclonic eddies have been invoked as powerful drivers of biogeochemical fluxes in the tropical ocean as well as significant vectors for inter-hemispheric transport. Such roles have aroused interest from scientists in a wide range of fields. The capability to remotely characterize these features as well as to predict their properties and dynamics should allow for more precise modelling of the role these mesoscale features play in the global ocean. In a regional context, the occurrence of these mesoscale events further contributes to the optical and biogeochemical complexity of Eastern Caribbean waters where other mesoscale phenomena, the discharge of two of the world's major rivers and coastal upwelling, sustain pronounced physical chemical and biological gradients. Knowledge of the interaction of these features with eddies will allow a more complete understanding of the optical heterogeneity of the region and its forecasting.

RELATED PROJECTS

A UPRM/NASA-sponsored research program, entitled Tropical Center for Earth and Space Studies, includes an oceanography component focused on identifying factors limiting biological carbon fixation in the Western Tropical Atlantic and Caribbean Sea. This program has funded the acquisition of instrumentation applicable to the effort here described and provided ocean color satellite imagery and ship time funding for the CaVortEx I cruise.